The X–ray afterglow of GRB030329 at early and late times

A. Tiengo[*†], S. Mereghetti[*], G. Ghisellini[**], E. Rossi[‡], G. Ghirlanda[*] and N. Schartel[§]

[*]*Istituto di Astrofisica Spaziale e Fisica Cosmica – Sezione di Milano "G.Occhialini" (Italy)*
[†]*Università degli Studi di Milano, Dipartimento di Fisica (Italy)*
[**]*INAF-Osservatorio Astronomico di Brera, Merate (Italy)*
[‡]*Institute of Astronomy, Cambridge (UK)*
[§]*XMM-Newton Science Operation Center, ESA, Vilspa (Spain)*

Abstract. Thanks to its extraordinary brightness, the X-ray afterglow of GRB030329 could be studied by *XMM-Newton* up to two months after the prompt Gamma-ray emission.

We present the results of two *XMM-Newton* observations performed on May 5 and 29, as well as an analysis of the *Rossi-XTE* data of the early part of the afterglow, discussing in particular the stability of the X–ray spectrum and presenting upper limits on the presence of X–ray emission lines.

INTRODUCTION

GRB030329 is an exceptional Gamma–ray burst for various reasons: it had a very large fluence of $\sim 10^{-4}$ erg cm^{-2} (30–400 keV, [1]), in the top 1% of all observed GRBs; its redshift is z=0.1685 ([2],[3]), which makes it the second nearest GRB; its optical transient was observed at magnitude 13 one hour after the explosion ([4],[5]); it is the first GRB unambiguously associated with a supernova ([6], [7]). The detailed studies in all wavebands made possible by the brightness of this event are yielding an unprecedented understanding on the jet structure, GRB energetics and circumburst environment. In particular, the X-ray afterglow could be studied at late times, with a sensitivity which was not achieved for previous bursts.

The spectral shape and the time evolution of the X–ray afterglow has been already reported and discussed in comparison with preliminary measurements of the optical afterglow by [8].

STABILITY OF THE NON–THERMAL X–RAY SPECTRUM

The first part of the afterglow of GRB030329 was studied with *Rossi-XTE*, which observed it twice in the first 30 hours since the burst explosion. For visibility constraints GRB030329 could not be observed by *XMM-Newton* until May. The first XMM observation was carried out 37 days after the GRB and a second one was done 23 days later.

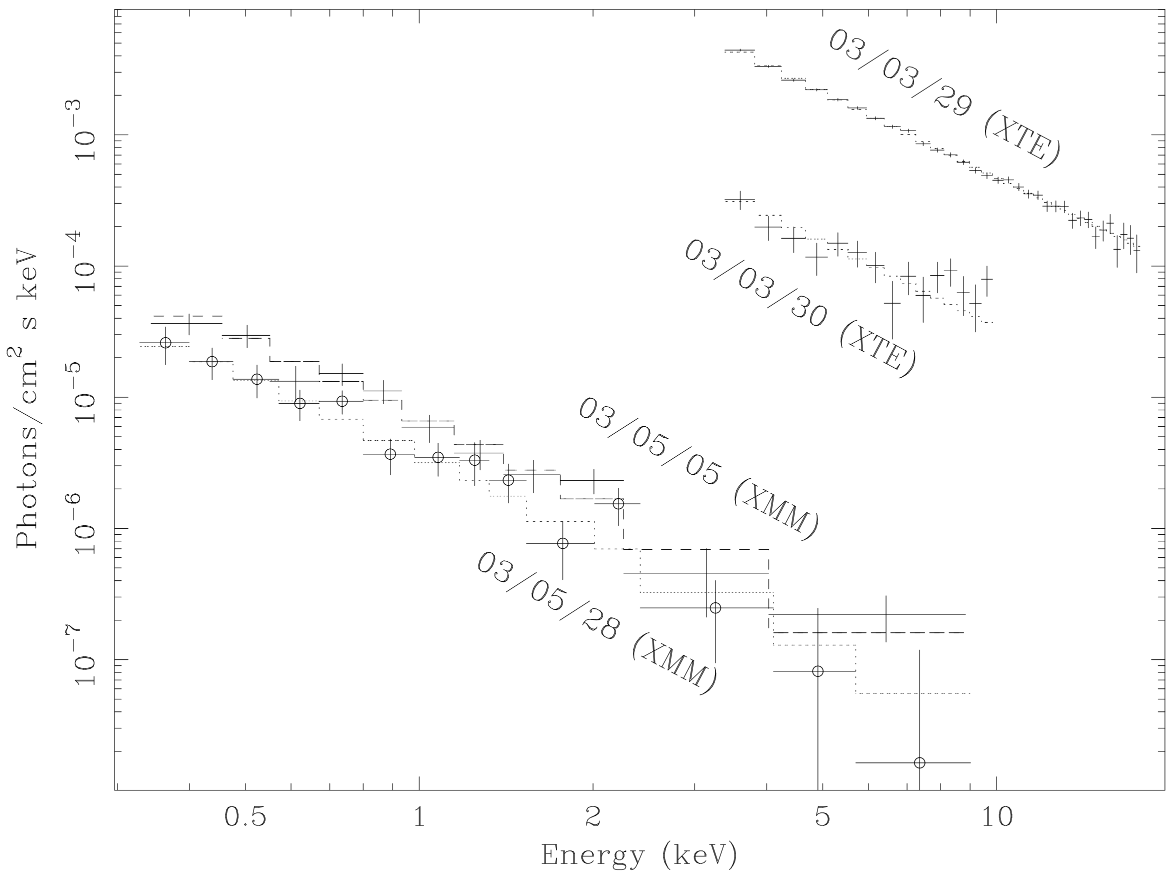

FIGURE 1. The X–ray spectra of the GRB030329 afterglow taken 5 hours, 30 hours (*Rossi-XTE* data), 37 days, and 61 days (*XMM-Newton* data) since the burst explosion. These unfolded spectra are obtained fitting the count spectra with an absorbed power law model with $N_H=2\times10^{20}$ cm^{-2} and Γ=2.2.

All the available X–ray spectra of the GRB030329 afterglow are well fitted by an absorbed power law with photon index $\sim$2.2 and absorption fixed to the Galactic value in that direction ($N_H=2\times10^{20}$ cm^{-2}). Such a non–thermal model is quite typical for X–ray afterglows, which are usually observed within few days since the GRB explosion. However, it is remarkable that it can fit also the afterglow two months after the GRB, when its flux has already decayed by $\sim$4 decades (see Fig.1).

The high quality of the EPIC spectral data allows us to investigate the possible alternative of non–thermal spectra for the late afterglow. We find that a fit to the summed spectra of the two *XMM-Newton* observations with a thermal plasma model (MEKAL) with Solar abundances is not acceptable (χ^2/dof= 62.6/30, see Fig.2). If the abundance is left free to vary, an acceptable fit is obtained (28.5/29) with kT=2.4$\pm$0.6 and a 3σ upper limit on the abundance of Z$<$0.2.

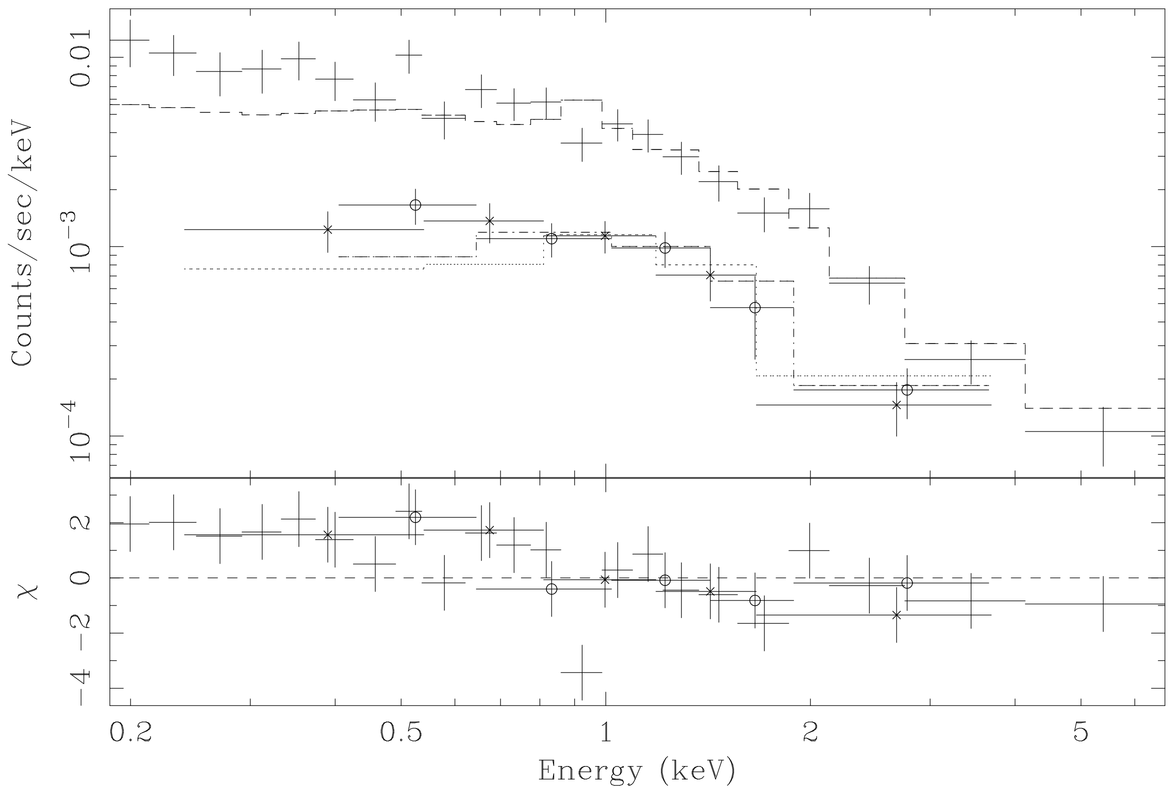

FIGURE 2. EPIC spectrum of the sum of the two *XMM-Newton* observations fitted with a MEKAL model (kT=3.8 keV) with Solar abundances and redshift fixed at z=0.1685 (absorption is fixed at the Galactic value $N_H=2\times10^{20}$ cm^{-2})

CONSTRAINTS ON EMISSION LINES

No discrete spectral features have been significantly detected in any of the X–ray spectra of the GRB030329 afterglow.

To derive upper limits on the presence of narrow emission lines in the late X–ray afterglow of GRB030329, we fitted the EPIC MOS and PN spectra of the sum of the two *XMM-Newton* observations with a model consisting of an absorbed (N_H fixed to the Galactic value) power law and a Gaussian emission line with σ=0. The line centroid was fixed to a grid of values covering the 0.5–6 keV energy band and all the 3σ upper limits on the corresponding normalizations were computed. The maximum values of the corresponding equivalent widths in different energy ranges are reported in Table 1. We consider them a reliable estimate of our sensitivity in detecting narrow emission lines in the EPIC data.

The detection of emission lines in the soft X–ray spectrum has been reported in the afterglows of GRB011211 ([9]), GRB030227 ([11]), GRB020813, and GRB021004 ([10]). In most of these cases the lines could be detected only during short time intervals in the early phases of the afterglow. All the lines were identified with transitions of rest–frame energies between 1.4 and 4.6 keV. For the redshift of GRB030329 their range corresponds to the 1.2–4 keV observed band. The two lines detected with the highest

TABLE 1. 3σ upper limits on emission lines

	Equivalent width
0.5–1 keV	$<$120 eV
1–1.5 keV	$<$150 eV
1.5–2 keV	$<$400 eV
2–3 keV	$<$700 eV
3–5 keV	$<$2000 eV
5–6 keV	$<$2800 eV

significance in all these cases (Si XIV and S XVI) have energies of 2.22 and 2.77 keV (1.9 and 2.4 keV at z=0.1685) and had equivalent widths smaller than 600 eV. These results can be compared with our upper limits for the afterglow of GRB030329 (Table 1).

Due to the combination of low redshift, small interstellar absorption and high quality spectra, we can put stringent limits to the presence of emission lines with rest–frame energy much lower than in any other GRB afterglow.

On the contrary, no significant information is obtained on the presence of a Fe-K line, which, at z=0.1685, is expected in the 5–6 keV band, where only few photons were collected in the EPIC instrument.

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